Radar Data and Lunar Polar Volatiles

Paul D. Spudis

Lunar and Planetary Institute

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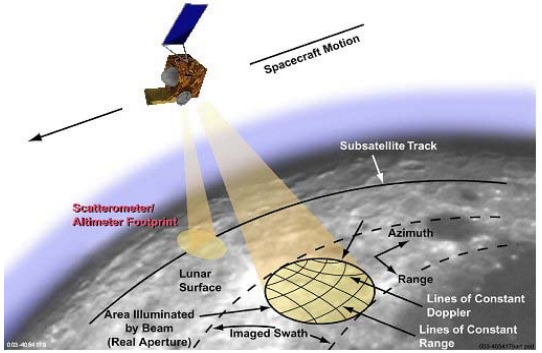
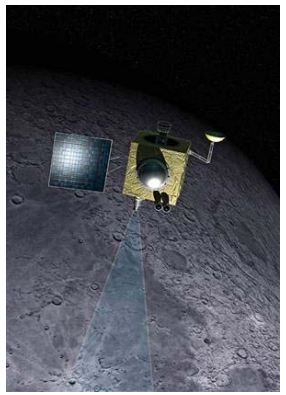
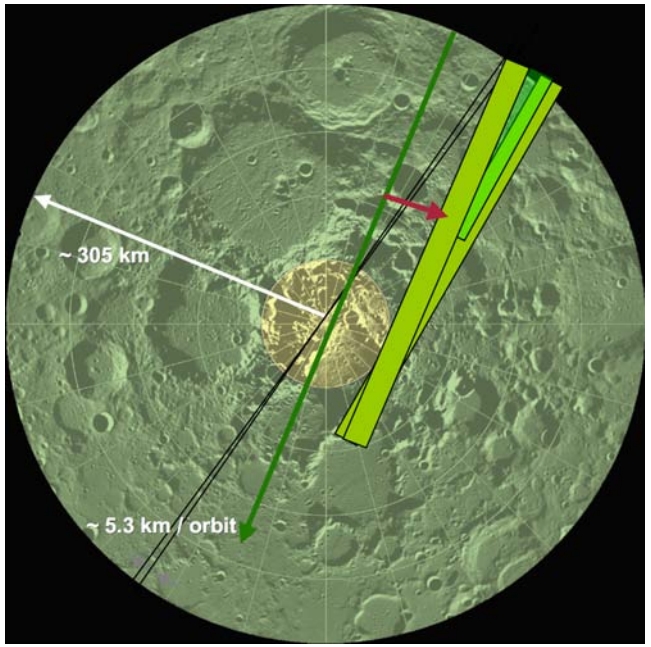
Radar as an ice detector

- Active sensing technique that “sees” into the permanently dark areas near the poles
- Mini-SAR and Mini-RF are hybrid architecture polarimetric radars, S-band (12.5 cm) that provide Stokes parameters for diffuse backscatter
- Mapped both poles of the Moon (> 80° lat.) at optimum viewing angles (~40°)
- Characterize the physical nature of the polar regolith and surface
- SAR mapping of about 2/3 of remaining lunar surface - image a variety of terrains of varying ages to provide comparative data base
- Mini-RF bistatic experiment - illuminate Moon with Arecibo transmitted S-band radar and receive on LRO MRF instrument
- **Radar detects surface roughness and RF transparent media. All factors affecting response in real geological settings are not fully understood**







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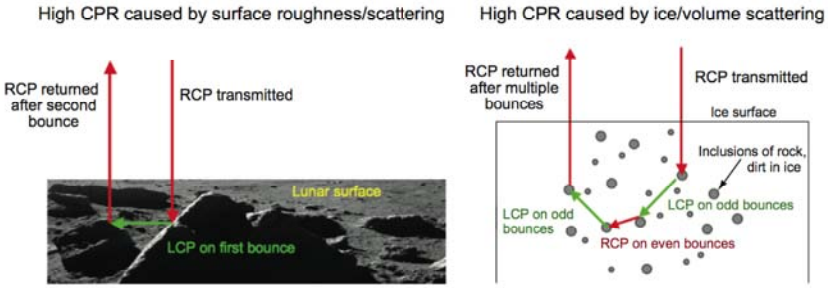
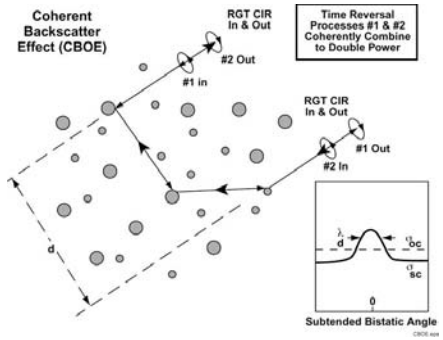
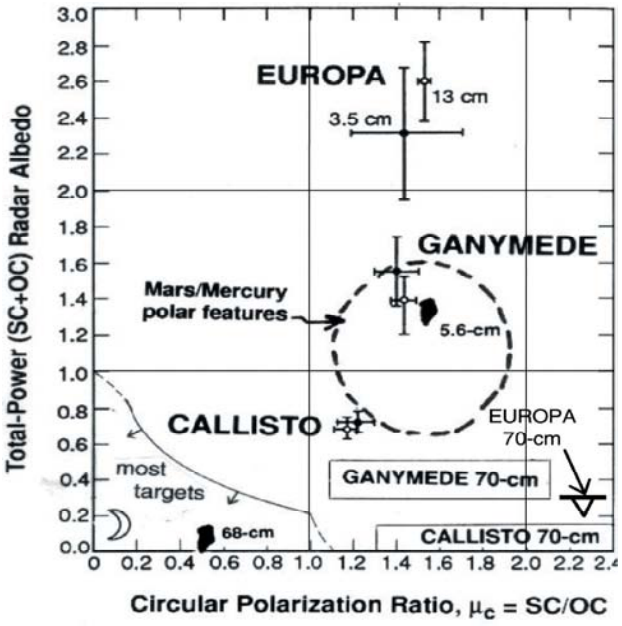
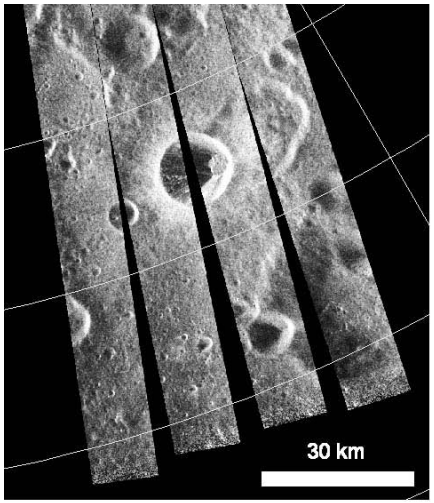
Circular Polarization Ratio (CPR)

- Ratio of received power in both right and left senses
- Normal rocky planet surfaces = polarization inversion (receive opposite sense from that transmitted)
- "Same sense" received indicates something unusual:
  - double- or even-multiple-bounce reflections
  - volume scattering from RF-transparent material (interferrometric addition of same sense waves - CBOE)
- High CPR (enhanced "same sense" reception) is common for fresh, rough (at wavelength scale) targets and water ice

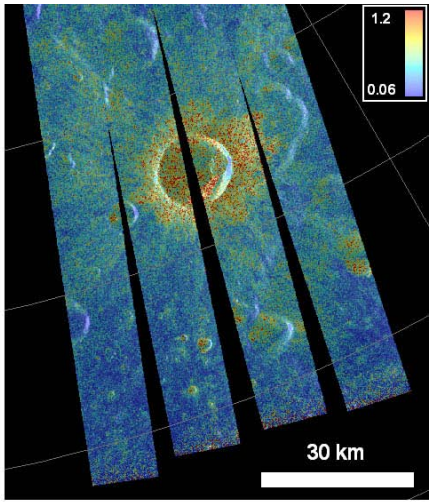






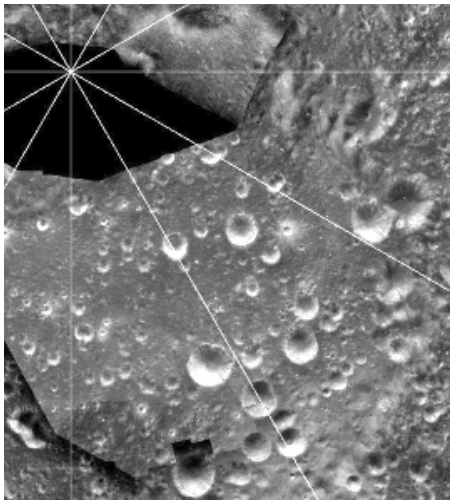


OS SAR image

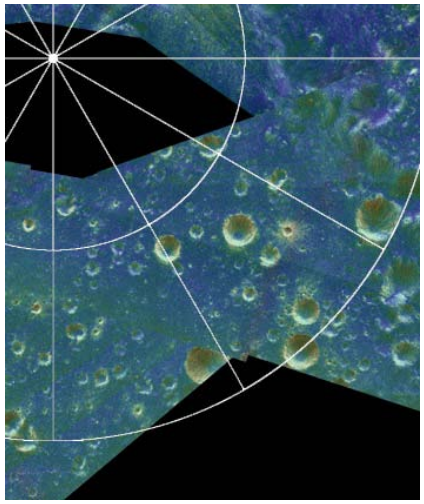


Main L
14 km diameter
81.4° N, 22° E

CPR image



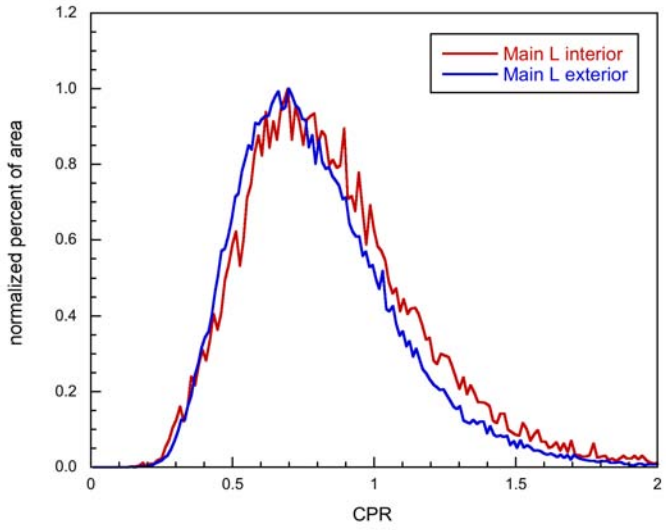
MRF S1

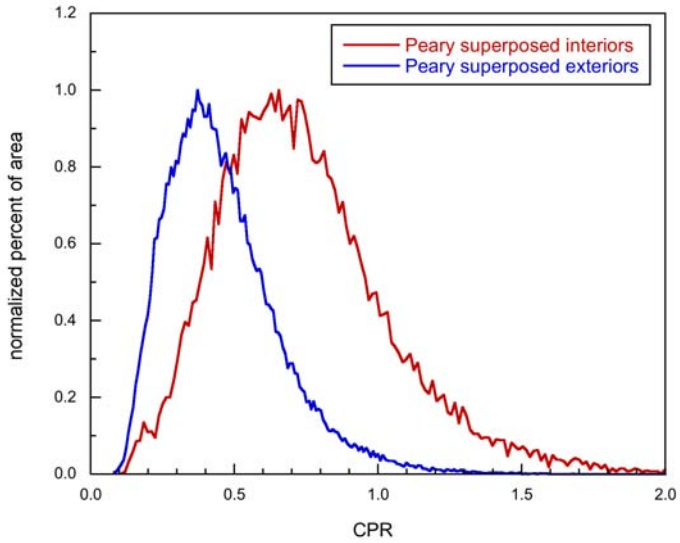


Peary floor

76 km diameter

CPR image

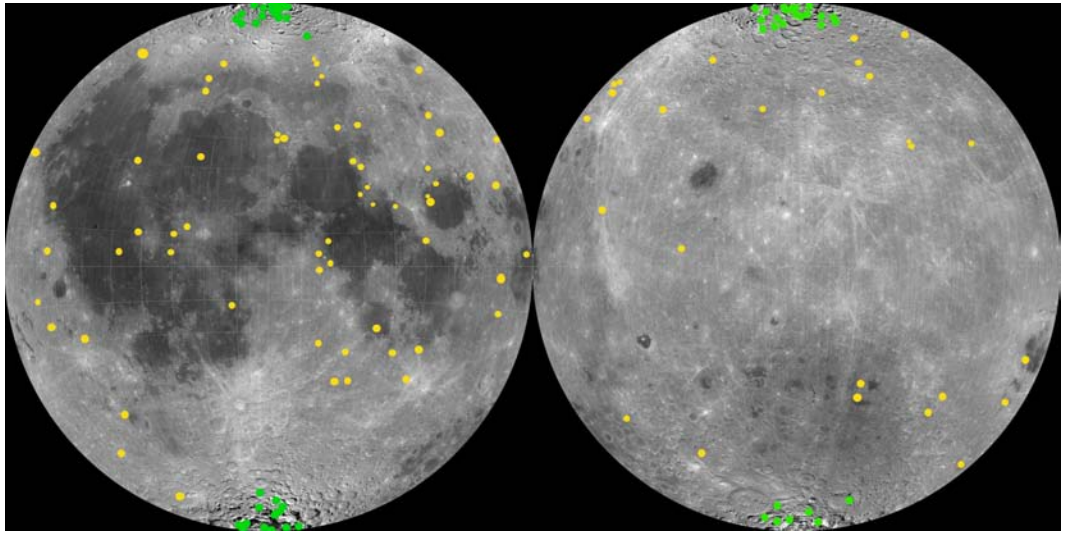


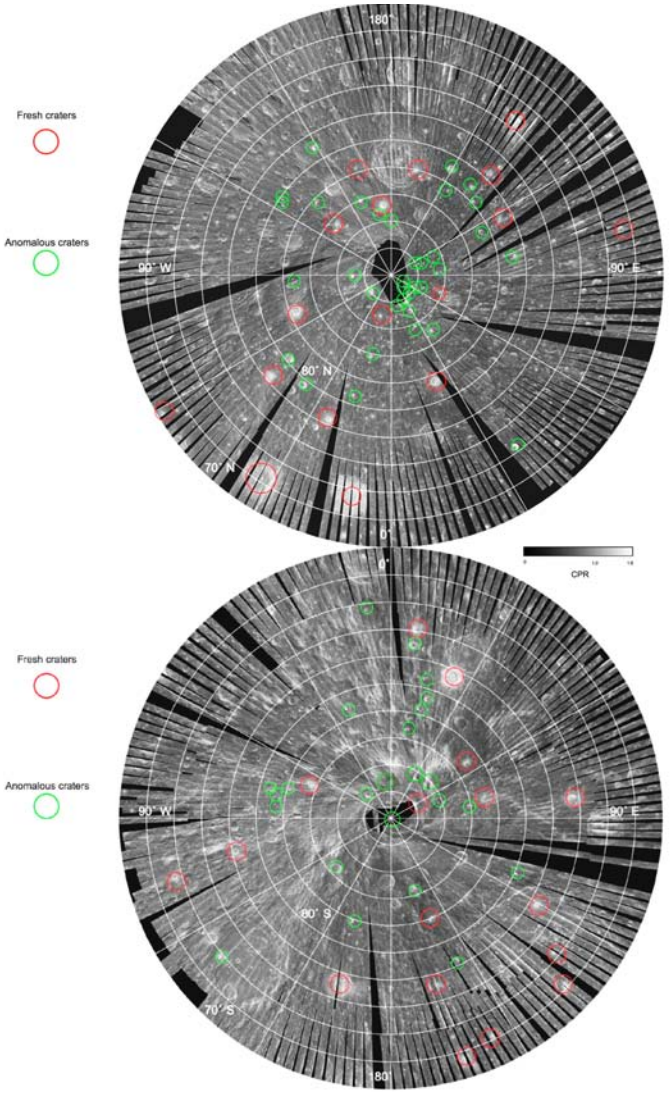


Distribution of Anomalous Craters

Higher density of anomalous craters in polar regions than rest of Moon (44 north, 28 south vs. 80 over remaining entire Moon)

Strong correlation of anomalous craters with areas of permanent darkness





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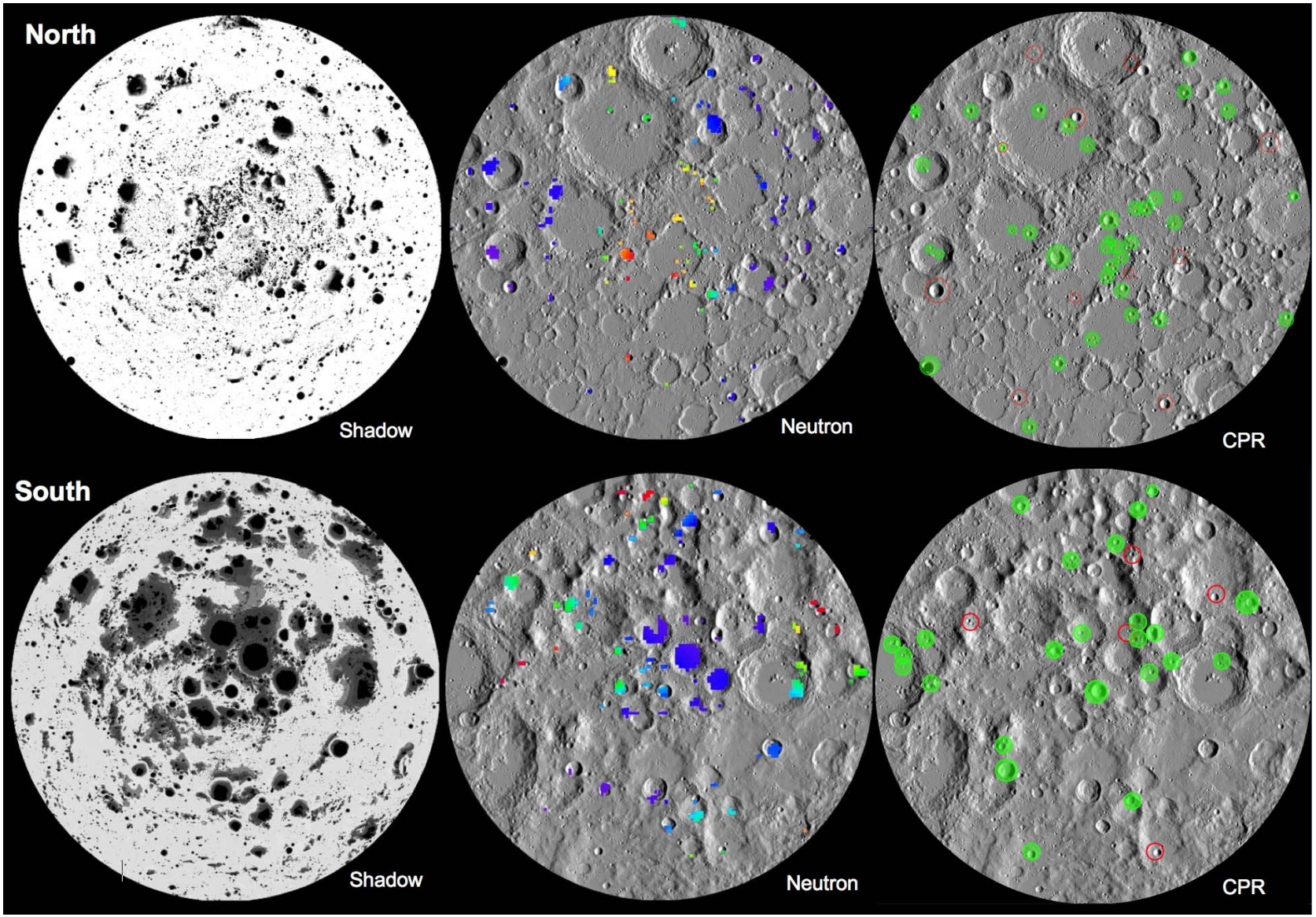
Polar Lighting, Neutron, Radar Data



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Mini-RF: Bistatic Experiment

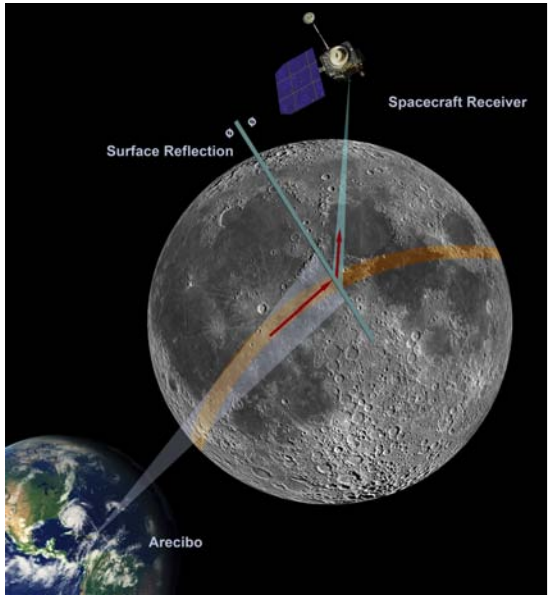
The Mini-RF transmitter ceased operating in December of 2010

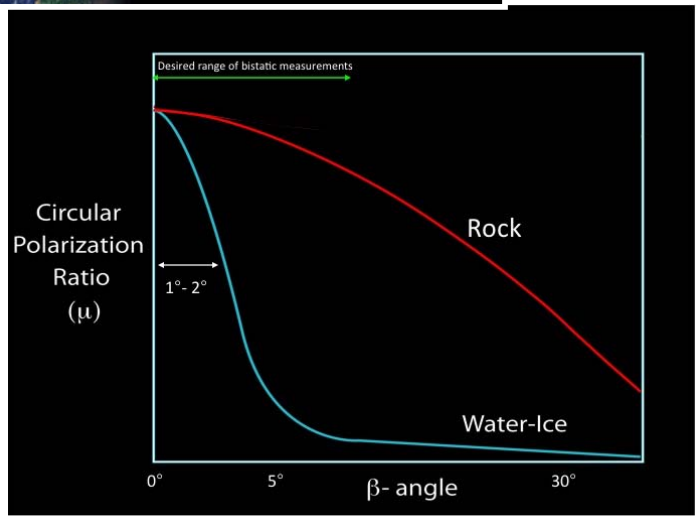
Mini-RF collected data in bistatic mode, using the Arecibo Observatory as a transmitter

- Provides information on scattering properties of lunar materials as a function of beta (phase) angle
- Data of nearside and polar targets has been successfully collected on 23 occasions

Goal is to determine if high CPR in polar dark craters is caused by ice or surface roughness

- Ice shows strong dependence on beta angle whereas rock does not





Bistatic Results

Theory vs. Observation

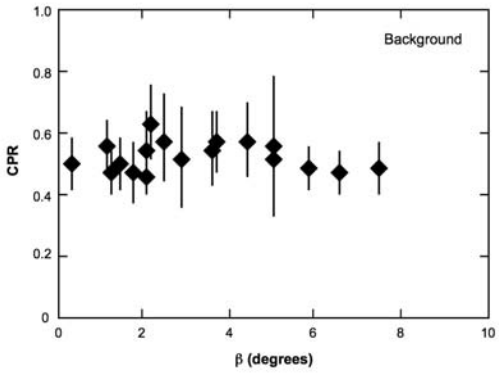
Bistatic data from Cabeus floor shows increasing CPR with decreasing β angle

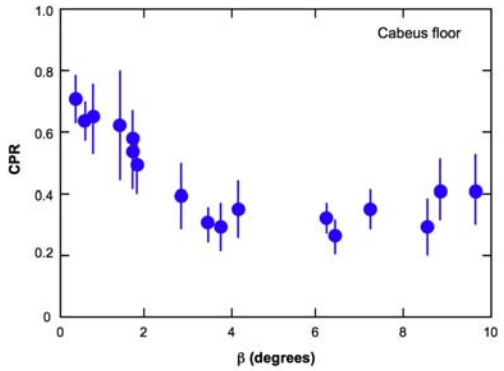
- In accord with theoretical pattern for ice deposits

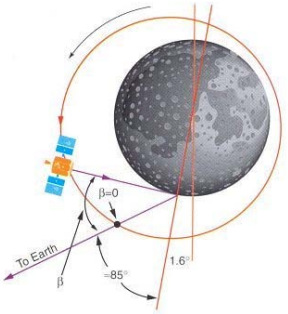
Background deposits show "flat" pattern with respect to beta, similar to rock targets

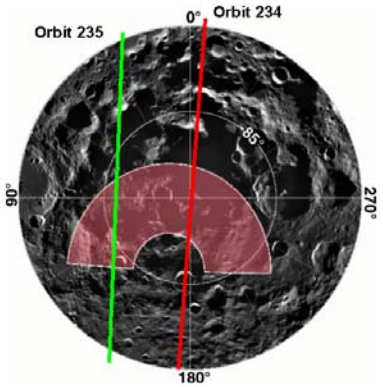
Conclude: Significant water ice in floor of Cabeus

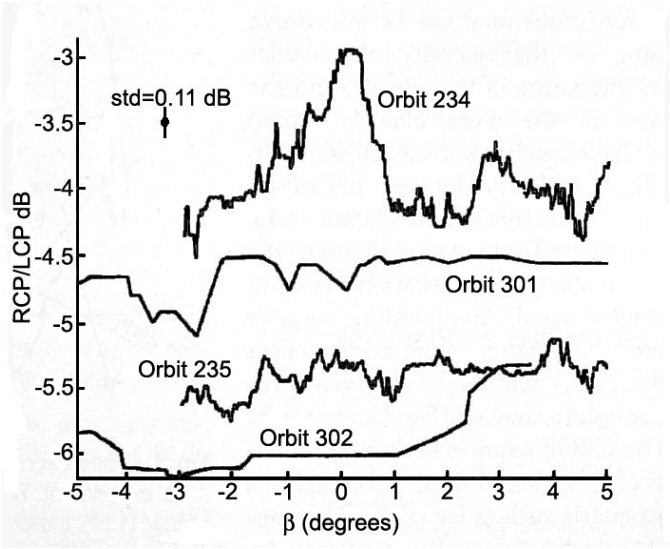
Clementine bistatic experiment (1994) - found "peak" in CPR symmetric around β=0











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Summary

- We have successfully mapped more than 98% of both lunar polar areas with imaging radar
- Areas of high CPR have been identified:
  - Some high CPR is clearly associated with surface roughness (e.g., Main L ejecta blanket)
  - Some deposits (e.g., near north pole on floor of Peary) show high CPR and are restricted to the *interior* of craters; these features are in permanent darkness.
  - Statistical analysis suggests that these features constitute a distinct population from normal, fresh crater high-CPR features
  - Modeling using new diffuse scattering model suggests anomalous craters are ice-rich
- Anomalous craters are found at both poles and correlate with Pixon model reconstructions of LP neutron data and areas of low surface temperature revealed by DIVINER
- If these anomalous deposits are water ice, over 600 million m^3 are present in vicinity of north pole
- Bistatic radar observations of Cabeus crater indicate peak at β=0, scattering behavior consistent with the presence of water ice